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COMMITTEE PRINT

PRODUCTION AND USE OF FERTILIZER FROM WESTERN MINERAL RESOURCES

TWO ECONOMIC AND TECHNICAL STUDIES OF A PROJECTED FERTILIZER INDUSTRY IN THE WEST FOR DEVELOPMENT OF MINERAL RESOURCES AND INCREASED CROP, CATTLE, AND WOOL PRODUCTION FROM RECLAIMED AND OTHER LANDS OF THE WEST

PART I
Development of Fertilizer Production and Use in the West

PART II
Proposed Manufacture of Complete Concentrated Fertilizer Mixtures at Green River, Wyo.

Prepared at the request of
Senator Joseph C. O'Mahoney, of Wyoming, Chairman of the Senate Committee on Interior and Insular Affairs

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FOREWORD

By Senator Joseph C. O'Mahoney, of Wyoming

To the Members of the Senate Interior and Insular Affairs Committee:

In accordance with our committee's continuing responsibility for development of natural resources and for the more effective use of reclaimed lands, I am submitting herewith for your consideration two studies on the development of a fertilizer industry in the West on a scale greatly expanded over present local production. The projected industry would be based on western mineral resources, primarily phosphate rock, natural gas, sulfur, and natural soda ash, and would utilize western hydroelectric, coal, or oil energy resources.

Large-scale production in the West of fertilizer from western resources available in western markets unburdened by cost of present long freight hauls would of course have far-reaching effects upon western agriculture, both as to crops and as to wool and cattle production. Fertilization of pasture lands, although relatively new on anything like a large scale, has proved its efficacy and value, as shown by tests conducted by various Western State agricultural agencies and reported by the National Fertilizer Association in its study, Protein Through Forage. In one test, for example, an average gain of 284 pounds of beef per acre was recorded during a 111-day period for steers grazed on irrigated pasture fertilized with superphosphate, as compared with a gain of only 163 pounds per acre on irrigated pasture not fertilized. Thus, the use of fertilizer on pasture increased beef production by 74 percent.

In another test, it is reported that pastures fertilized with superphosphate and manure produced nearly 100 percent more forage than did unfertilized areas. Butterfat produced from the forage during a 2-year period averaged approximately 200 pounds per acre compared with 103 pounds from unfertilized areas. Reports of still another test showed that over a 5-year period the annual average yield of irrigated fertilized pasture was equivalent to 6.4 tons of alfalfa hay as compared with 3.7 tons on irrigated but nonfertilized pasture.

The importance of such results on a large scale can be visualized when the ratios are applied to a Western State such as Wyoming where we have nearly 15,000 ranches and farms, comprising some 34½ million acres, on which run approximately 2 million sheep and more than a million beef and dairy cattle.

A joint report by the United States Department of Agriculture and the Association of Land-Grant Colleges and Universities, issued in September 1952, entitled "A National Program for More Effective Use of Fertilizer and Lime," states:

> Fertilizer and lime, when used under proper conditions and in conjunction with other desirable practices, can bring about a very substantial increase in farm production and at the same time make an indispensable contribution toward conserving and improving the productivity of our farm land. The importance of fertilization and liming to the achievement of these objectives is being recognized more and

more by farmers and professional workers in agriculture as is the proper utilization of farm manure and other organic materials. Economic studies show that the expanded use of the fertilizer, lime, and other improved practices needed to accomplish these objectives is profitable. * * *

New information on the most effective use of fertilizer and lime supplies is coming out of a Nation-wide survey by the National Soil and Fertilizer Research Committee of the State agricultural experiment stations and the USDA. Where balanced supplies of plant nutrients are used in combination with other good management practices, striking results may be expected from increased fertilization. For the country as a whole the greatest opportunities for increasing yields through fertilization are in grain and forage crops, which receive comparatively low rates today.

The corn crop offers a spectacular opportunity for increased yields through higher rates of fertilization. In the South, a combination of heavier fertilization, adapted hybrids, and other good management practices could triple the present average yield of 26 bushels per acre. North Central region growers could increase yields on corn by 250 million bushels, by tripling the current rather low average rates of fertilization.

Increased fertilization would boost wheat yields 48 million bushels in the Western States, and would increase average yields in the Eastern States by more than one-third.

Grass, hay, and permanent pasture offer a promising source of increased production, if the current low average rates of fertilization are greatly increased. A 30-percent increase in pasture yields could be achieved in the northeastern region merely by using the same rate of fertilization now used on corn. When much higher rates of fertilization have been combined with the use of improved grasses and legumes, yields have been increased more than threefold.

The first of the studies contained in this print was prepared at my request in the Office of Industry and Commerce, United States Department of Commerce. It deals ably and concretely with the vital questions of potential markets, sources of raw material and probable costs for an extended fertilizer industry for the West and reviews the agricultural and industrial benefits that would accrue to the Mountain States and other parts of the West through the development of such an industry. In addition it summarizes some of the aids which State and Federal agencies can provide to promote the establishment of such an industry.

The other study was prepared by Mr. Robert D. Pike, a private consulting chemical engineer of very high standing, who had a leading part in the establishment of the $20 million Westvaco facility in Sweetwater County, Wyo., for the development of the great natural soda-ash deposits there. It deals with the large-scale use of the "base exchange" process for production of a high-concentrate plant food that could readily be adapted to the varying needs of diverse markets.

Although for purposes of economic analysis, both studies are based on an industry to be established in Wyoming, most of the data is generally applicable to the other three Western States in which large deposits of high-grade phosphate rock occur—Utah, Montana, and Idaho. This is particularly true of the Department of Commerce study; Mr. Pike's, which is based on processes using soda ash, naturally is centered on the Wyoming natural soda-ash deposits.

Just 10 years ago, in 1942, in a report on the resources of Wyoming and surrounding States prepared at my request, the Federal Power Commission predicted that, in the not too far distant future, an integrated chemical and fertilizer industry would be established in the Rocky Mountain area, probably in the vicinity of Green River, in southwestern Wyoming. The great chemical operations now taking

place there bear out, in part, this long-range view of the industrial and agricultural potentialities of the West. It should be noted also that at least one pioneer venture producing high-grade fertilizer from western mineral resources is already under way in Wyoming, that of Phosphate Mines, Inc., at Kemmerer, operated by Mr. Matt Bertagnolli and group of associates. However, Mr. Bertagnolli's enterprise is on a smaller scale and uses a process somewhat different from those subject to analysis in the studies of the Department of Commerce and Mr. Pike.

These reports are submitted to the committee as a basis for consideration of committee action leading to further development of the mineral resources of the West and to the more effective use of western pastures and farms on reclamation lands and others.

JOSEPH C. O'MAHONEY, *Chairman.*

PART I

DEVELOPMENT OF FERTILIZER PRODUCTION AND USE IN THE WEST

Prepared in the Department of Commerce under the general direction of H. B. McCoy, Director, Office of Industry and Commerce

By Jesse J. Friedman, Chief, Economic Review staff [1]

I. Introduction

This is an outline of a program for furthering the industrial and agricultural development of the West by promoting the production and use of fertilizers in this area on a large scale from indigenous western mineral resources. The purpose is twofold:

(*a*) to contribute significantly to the industrial build-up of the area;

(*b*) to increase substantially the productivity of the land, particularly that suitable for pasture.

A primary mineral resource on which an expanded fertilizer industry in the West can be built is phosphate rock. The program herein outlined is applicable to the four-State area—Idaho, Montana, Utah, and Wyoming—which contains 7 to 8 billion tons of phosphate rock, over 60 percent of the total known deposits of the country. The other 40 percent is divided between Florida, which has approximately 38 percent, and Tennessee, which has approximately 2 percent. Thus, the nearest producing fields—which now provide most of the phosphate rock used by the fertilizer industry—are on the other side of the Continent from the area here considered.

In the four-State area, the easternmost deposits—which have the advantage of proximity to the great fertilizer markets of the Midwest—are located in central Wyoming. The fertilizer potentialities of Wyoming are used for purposes of illustration. With appropriate changes, the data and conclusions cited below would be equally applicable to Idaho, Montana, or Utah, where great potentialities exist for large-scale expansion of present fertilizer production activity.

II. Increased Fertilizer Use in the West

The availability of abundant fertilizer from western sources at costs not burdened with long freight hauls from distant points unquestionably would spur greatly the use of fertilizer in the West. Phosphorous, nitrogen, and ammonium sulfate are the chief fertilizer materials required for crop and pasture lands in the area. Potash is naturally abundant in most western soils and therefore is not emphasized in this study.

[1] Grateful acknowledgment is made to Dr. John R. Skeen, technical consultant to the Economic Review staff, who prepared most of the technological data used in this report.

The magnitude of economic benefits to farmers throughout the West resulting from expansion of fertilizer production within the region is apparent from even a cursory examination of the data.

The most authoritative and current information on the subject of fertilizer use and needs in each State and section of the country is contained in the study conducted cooperatively by the Association of Land-Grant Colleges and the Department of Agriculture in 1951 and 1952, and published in June 1952 under the title "Agriculture's Capacity To Produce: Possibilities Under Specified Conditions." The purpose of this exhaustive study was to appraise agricultural production possibilities under conditions of mobilization and to estimate the quantities of key resources needed to achieve the production attainable under those conditions. As part of this project, State-by-State appraisals of agricultural capabilities attainable by 1955 were carried out by State productive capacity committees appointed by the State experiment station directors and made up of production specialists, agricultural economists, extension workers, and other State and Federal agricultural workers who were thoroughly familiar with agricultural conditions in that State.

The State-by-State use of fertilizer in 1950 and estimated needs for 1955 are shown in the following release by the Department of Agriculture:

UNITED STATES DEPARTMENT OF AGRICULTURE, JANUARY 31, 1952

ESTIMATES OF QUANTITIES OF COMMERCIAL PLANT NUTRIENTS USED IN 1950 AND OF THOSE NEEDED FOR LEVEL AND PATTERN OF PRODUCTION ATTAINABLE IN 1955

(The data below were tabulated from reports of State productive capacity committees in a Nation-wide study undertaken cooperatively by the land-grant colleges and the Department of Agriculture to appraise the productive capacity of American agriculture in the mobilization period and the critical materials needed to achieve the production which the committees believed to be attainable by 1955. These estimates indicate that 70 percent more fertilizer than was used in 1950 would be needed to achieve this level and pattern of production, including 93 percent more nitrogen, 54 percent more phosphoric acid, and 77 percent more potash.)

State and region	1950			1955 attainable		
	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Maine	12,870	20,593	23,470	15,980	25,307	26,587
New Hampshire	836	3,837	2,171	1,082	5,150	2,842
Vermont	1,521	6,911	3,758	2,323	10,414	6,032
Massachusetts	4,417	8,875	6,422	4,465	9,189	6,519
Rhode Island	649	1,554	1,337	877	1,730	1,556
Connecticut	6,612	8,277	8,046	7,963	10,567	10,688
New York	23,913	81,888	34,053	33,000	90,000	40,000
New Jersey	11,951	24,953	20,890	18,964	44,731	45,811
Pennsylvania	20,611	83,820	41,332	27,191	113,967	98,087
Delaware	2,089	6,650	4,886	3,048	7,213	6,098
Maryland	6,319	30,252	17,351	21,433	74,054	47,094
Northeast	91,788	277,610	162,716	136,326	392,322	291,314
Ohio	28,860	117,512	81,520	46,585	144,409	100,115
Indiana	34,491	130,464	97,291	141,002	227,462	200,218
Illinois	15,804	[1] 201,055	48,688	46,340	[2] 283,760	95,086
Iowa	13,616	48,336	12,736	70,069	103,105	34,943
Missouri	21,865	52,641	28,047	90,000	136,000	70,000
Corn Belt	114,636	550,008	268,282	393,996	888,736	500,362
Michigan	9,548	62,738	39,360	16,436	92,171	69,679
Wisconsin	12,671	49,601	51,243	45,162	105,702	116,250
Minnesota	6,465	41,542	20,992	12,010	63,950	31,975
Lake States	28,684	153,881	111,595	73,608	261,823	217,904
Virginia	26,862	80,906	43,723	35,877	104,159	63,568
West Virginia	2,250	17,000	4,450	3,700	24,500	6,200
North Carolina	92,148	146,276	104,142	133,200	211,567	199,268
Kentucky	21,758	75,221	27,198	28,270	96,505	35,915
Tennessee	23,343	56,885	28,834	32,728	63,070	43,547
Appalachian	166,361	376,288	208,347	233,775	504,801	348,498
South Carolina	52,126	72,756	48,243	81,644	123,133	89,735
Georgia	63,164	107,101	67,461	100,028	140,073	125,481
Florida	42,704	64,436	63,584	72,494	80,880	88,421
Alabama	61,711	97,669	53,047	106,283	126,475	86,393
Southeast	219,645	341,962	232,335	360,449	470,561	390,030
Mississippi	84,961	46,395	23,807	157,031	95,874	48,540
Arkansas	38,700	35,500	23,550	66,416	76,873	48,025
Louisiana	30,155	25,261	12,084	40,634	30,562	14,101
Mississippi Delta	153,816	107,156	59,441	264,081	203,309	110,666
Texas	28,643	78,877	11,844	64,667	122,281	19,337
Oklahoma	5,000	30,000	3,000	29,823	68,298	7,060
Southern Plains	33,643	108,877	14,844	94,490	190,579	26,397
North Dakota	884	6,037	40	4,179	17,575	150
South Dakota	501	1,347	40	7,134	10,768	0
Nebraska	12,450	1,495	0	67,960	16,580	0
Kansas	16,861	34,464	3,195	50,396	55,070	5,925
Northern Plains	30,696	43,343	3,275	129,669	99,993	6,075
Montana	1,943	4,370	45	4,676	9,930	90
Idaho	9,006	20,760	555	14,950	26,276	555
Wyoming	386	1,752	0	2,320	3,839	0
Colorado	2,432	6,350	0	6,116	10,271	0
New Mexico	2,208	4,048	40	7,490	8,663	40
Arizona	18,068	8,779	2,185	27,245	13,115	2,185
Utah	2,286	2,453	0	4,893	4,339	0
Nevada	131	550	0	876	2,476	0
Mountain	36,460	49,062	2,825	68,566	78,909	2,870
Washington	8,839	9,743	3,443	23,328	12,733	3,988
Oregon	15,783	10,594	2,557	27,018	15,556	4,659
California	125,653	59,867	12,216	171,985	101,509	13,379
Pacific	150,275	80,204	18,216	222,331	129,798	22,026
United States	1,026,004	2,088,391	1,081,876	1,977,291	3,220,831	1,916,142

[1] Includes 137,100 tons of P_2O_5 in the form of rock phosphate.
[2] Includes 211,000 tons of P_2O_5 in the form of rock phosphate.

It will be seen from the figures that for the entire area west of the Mississippi River, fertilizer requirements in 1955 to meet attainable levels of farm production are estimated by the State committees at 622,000 tons of nitrogen (N) content, as against 320,000 tons used in 1950; and at 607,000 of phosphorous pentoxide (P_2O_5) content as against 342,000 tons used in 1950.

In the Mountain States, the need for phosphate fertilizer to meet attainable production levels is estimated by the State committees at about 79,000 tons of P_2O_5 content as against about 49,000 tons actually applied to the soil in 1950; for nitrogen, the estimated need for 1955 is about 69,000 tons against 36,000 tons used in 1950.

In the case of the Northern Plains States—Kansas, Nebraska, and the Dakotas—requirements of phosphate fertilizer to meet attainable levels of agricultural production are estimated by the State committee to reach 100,000 tons of P_2O_5 content in 1955 as against only 43,000 tons actually used in 1950. Requirements of nitrogen fertilizers in the same States are estimated at about 130,000 tons of nitrogen content for 1955, as compared with only 30,000 tons used in 1950.

The most striking increase in fertilizer needs in this area is recorded for Nebraska, where fertilizer use is expanding rapidly. For that State, 1955 requirements are more than 5 times the amount used in 1950 in the case of nitrogen, and more than 10 times the amount used in 1950 in the case of phosphate fertilizers. For specified crops and pasture, it is contemplated that 3,649,000 acres of land in Nebraska would receive fertilizer under attainable levels of production in 1955, as against 805,000 acres in 1950. According to the report of the State Productive Capacity Committee for Nebraska, even these estimates of fertilizer application requirements seem on the low side. A new $25 million plant at La Platte, near Omaha, Nebr., producing about 62,000 tons of nitrogen a year for fertilizer use, was certified by the Government for accelerated tax amortization benefits earlier this year; this plant is now under way and is scheduled for completion early in 1954. Another $27 million plant at La Platte, for producing 200,000 tons of nitrophosphate fertilizers a year (containing 30,000 tons of P_2O_5 and 30,000 tons of nitrogen) plus another 32,000 tons of nitrogen for other fertilizer products, has been proposed by the same company and is under consideration by defense production authorities.

Other significant data concerning fertilizer use by crops and by regions, as reported by the State committees, are shown in tables A through E at the end of this report.

Land receiving water

In the case of western lands which are already receiving sufficient water and are devoted to raising crops or livestock, tests have shown that large increases in production are attainable by the application of greater quantities of suitable fertilizer to the soil. Many such lands are at present receiving little or no fertilizer. This appears to be particularly true for lands available for forage and pasture. A quarter century ago, the use of fertilizer on pastures was practically unknown in the United States. Slowly but surely, however, the practice has been proven and adopted in one section of the country after another. It is reported that last year, about 1 million tons of various fertilizer mixtures was applied to pasture in the country as a whole.

All estimates of future food and fiber needs of the country point to further increasing emphasis on the importance of lifting our production of sheep and cattle. Expanding the capacity of existing land to support sheep and cattle is thus of national importance, as well as a source of profit to the growers and the areas affected. Adequate fertilization of pasture lands is one of the most effective means available for maintaining and increasing animal production.

INCREASED YIELDS FROM PASTURES

In fact, according to the National Program for More Efficient Use of Fertilizer and Lime, announced jointly on September 11, 1952, by the Department of Agriculture and the Association of Land Grant Colleges, forage crops rank with grain in providing "the greatest opportunities for increasing yields through fertilization." In the West, where millions of sheep are raised on grass alone, phosphate fertilizers in particular are needed to replace the phosphorous removed from the soil year after year in grazing crops, if the soil is to continue to provide the needed forage.

In some cases, soil alkalinity, which is widespread in the West, has tended to inhibit profitable use of fertilizer on pasture lands. Increased availability of various fertilizer materials in forms well suited to typical western soil conditions, including alkalinity, should tend to promote fertilizer use and thus to facilitate sheep and cattle raising in Wyoming and other Western States on a scale even larger than at present.

Irrigable land

In addition to the potential increases in output to be achieved by adequate fertilization of land already receiving sufficient water, there are large irrigable areas in the West which now lack a full supply of water.

The Bureau of Reclamation has estimated that, under the current state of technical knowledge and present repayment requirements, there are about 16 million acres of land in the West not yet irrigated which are capable of irrigation, exclusive of range land susceptible of irrigation for pasture. In addition to this new land which can be reclaimed, about 7 million acres of the 22 million acres already under irrigation are estimated to require supplements to their present water supplies to permit adequate cultivation.

Some of the irrigation projects needed to realize this potential are already planned or under way. During the next 2 years, Bureau of Reclamation projects alone are to provide a full supply of water to about 1 million acres of new land and a supplemental supply to about 2 million acres of existing land.

SPUR TO IRRIGATION

Water is essential to cultivation, but water is not enough, of itself, to assure optimum production and profits. Aside from the condition of land at the time of reclamation, each crop removes minerals from the soil which must be replaced if yields are to be sustained or increased. Impressive results have been achieved by use of fertilizers on irrigated lands, particularly pastures. Details are available from

the Department of Agriculture and the various State agricultural experiment stations in the West.

More irrigation is needed to bring new lands under cultivation for crops and pasture. The potential returns from such lands are, of course, a major factor in determining whether or not the investment required for irrigation is justified.

By increasing yields and profits, availability of abundant fertilizer in Wyoming and other Western States can place irrigation projects on a more economic basis, and thus accelerate the development of new lands. The development of the lands, in turn, would open new markets for the fertilizer to be produced in the West.

FERTILIZER OUTLOOK

One of the most cogent statements concerning the prospects for profitable use of fertilizer and continued increase for fertilizer demand under varying economic conditions, with particular reference to grasslands, was published recently by Dr. S. E. Johnson, Assistant Chief, Bureau of Agricultural Economics of the Department of Agriculture. Dr. Johnson concludes as follows:

WHY FARMERS HOLD BACK

All available information indicates that most farmers are using less fertilizer than would be profitable at prevailing prices. Why? Part of the reason is undoubtedly a feeling that a margin of safety is needed in case of unfavorable growing conditions or much lower prices. But perhaps the most important factor is that information is not available concerning the most profitable rates under different conditions. We need more localized testing of crop responses to different rates of fertilizer use. Then these responses need to be translated into added dollars of net income from the increased use of fertilizer. In other words, we need economic interpretation of fertilizer responses to show dollars of net income under different price conditions. There is also need for a survey of present usage of fertilizer by crops including pasture in different areas to compare with applications that would be most profitable under different prices in areas of broadly similar soils and other production conditions.

In areas in which a wide gap appears between the quantities of fertilizer that farmers are now using, and the most profitable rates under different cost and price conditions, the usage curve could continue to move up even with some decline in farm prices. Therefore, if we should have a recurrence of price and income changes that we experienced in the period 1947–50, this might not stop the upward trend in use of fertilizer. It undoubtedly would slow it down, because more fertilizer would be used if farm incomes were higher. But fertilizer consumption might continue to increase despite lower farm prices if supplies were freely available, and if cost-price relationships still favored higher use.

BALANCED PRODUCTION

The question is frequently raised: What about the effect of using more fertilizer on market supplies and prices of farm products? Is there danger that fertilizer use will be expanded so rapidly that resulting production increases will create farm surpluses, and that price difficulties will be encountered? These are questions of balancing production under given price conditions. If changes occur in consumer demand to require transition adjustments in farming, the adjustments are likely to involve shifts in use of fertilizer. For example, more farm resources may need to be shifted to livestock production. This would mean using relatively more fertilizer on grasslands, and a rebalancing of production would be called for. Although farmers would need to produce a different combination of products, markets are likely to be available for the total farm output, unless we should encounter severe depression.

We might illustrate this point with the situation that prevailed immediately following World War II. If we had not been short of feed and could have increased livestock production more rapidly, we could have eliminated most of our

cash crop surplus worries in 1949 and 1950. Markets were available for the total output of our farm plant. But we were not able to adjust rapidly toward more hay and pasture and more meat and milk. In view of the need for flexibility in production to meet changing demands, added emphasis should be given to grassland farming as a balance wheel in adjustment. Establishment of improved stands of grasslands will require heavy applications of fertilizer in many areas.

THE OUTLOOK CAN BE BRIGHT

The factors that seem to have a bearing on the profitable use of fertilizer in the next 4 or 5 years can be summarized about as follows: Most farmers today are not using fertilizer at the rates that would be most profitable under present price and cost conditions. This is perhaps partly explained by the risk of lower prices and unfavorable growing conditions. But in many instances farmers do not have adequate information to determine the most profitable use. More local testing is needed, and more information on what constitutes profitable use under different price and cost conditions.

Because of the gap between prevailing use and profitable use, total fertilizer consumption could continue to increase even if farmers should encounter lower farm prices. This is what happened from 1947 to 1950. But use of fertilizer would increase faster under more favorable conditions.

If transition adjustments are required, they are likely to involve more emphasis on grasslands. Establishment and maintenance of improved stands of grass will require much fertilizer.

If consumer purchasing power is maintained at fairly high levels, the upward expansion in fertilizer use during the next 4 or 5 years may continue at about the same rate as in the 1940's. This assumes that supplies are freely available at cost-price relationships that encourage higher use. In most areas there is tremendous flexibility in the profitable use of fertilizer by farmers on different crops and grasslands. The quantities used therefore could be increased a great deal by educational and other programs that would bring out the advantages of higher use under favorable price-cost conditions. If we should encounter either a severe depression or all-out war, all bets are off.[1]

III. Plan of Production

As a basis for discussion, an ambitious but economic project combining the features most suitable for location in Wyoming might consist of an integrated plant costing about $15 million, using the wet process, and capable of producing 80,000 to 125,000 tons of fertilizer materials annually, depending upon the products made.

Production process

The two main processes for making phosphate fertilizers are (1) the wet process, in which phosphate rock is treated with acid to make superphosphates; (2) the electric furnace process, in which phosphate rock is reduced to elemental phosphorus, which is then built up into superphosphates.

The electric-furnace method requires substantial quantities of power, vastly more than that required by the wet process. Generally the electric-furnace method is not as economical for producing bulk fertilizer materials as the wet process except where power rates are extremely low. While comparative cost calculations are subject to a considerable margin of error, estimates indicate that when power is at 2.5 to 3 mills, electric furnace costs are in range with wet process costs for superphosphate production. Power is not now generally available for phosphate development at this rate, although rates may well be lower in the future as power development in the West expands. According to the Interior Department, for example, most recent quo-

[1] Sherman E. Johnson "Profitable Use of Fertilizer: A Forward Look," National Fertilizer Review, July-August-September 1952.

tations of private power concerns in the phosphate area of southeast Idaho are above 6 mills per kilowatt-hour for firm industrial power.

The production plan presented below is intended to suggest broadly, without burdening the discussion with engineering details, the type and size of production units appropriate to the condition outlined. As a basis of planning, the wet process is used for purposes of discussion in this report. In addition, it is planned to use nitric acid and ammonia to make nitrophosphates. The use of nitric acid and ammonia is a proven process, in use abroad for some time and just coming into operation in the United States after extensive testing by TVA.

Size of plant

The plant would be integrated, producing its own sulfuric and nitric acid requirements, and preferably producing also its own sulfur requirements for the sulfuric acid. Such an integrated plant would consist of the following basic production units:

	Capacity (tons per day)
Ammonia	32
Nitric acid	55
Sulfur recovery	35
Sulfuric acid	100
Nitrophosphates (TVA)	175
Other superphosphates	175
Ammonium sulfate	30

The estimated cost of such a plant would be about $10 million.

The chief advantages of the proposed production plan are as follows:

1. Almost one-half of the acid requirement for the fertilizer plant would be furnished by production of nitric acid from ammonia. Besides reducing the sulfur requirement, the production of ammonia and nitric acid requires no raw materials other than nitrogen which is obtained under pressure from the air, and hydrogen which is obtained readily from natural gas.

2. At little additional investment cost, sufficient nitric acid and sulfuric acid capacity would be installed, beyond the requirements for nitrophosphates (TVA) and superphosphates alone, to permit the production of ammonium sulfate.

3. Self-sufficiency in providing the acid requirements of the plant would make possible large savings in operating costs. Acid costs are the second largest factor in operating costs for an ordinary superphosphate plant, normally constituting about 40 percent of total operating costs.

4. The proposed plan permits considerable flexibility in producing to meet changing requirements for various fertilizer combinations in the future—nitrogenous or phosphoric, concentrated or ordinary.

Since potash is naturally abundant in the soil throughout most of the West, it is not emphasized in the proposed production plan. Potash consumption in the Pacific, Mountain, and Northern Plains States totaled 24,000 tons in 1950. The State productive capacity committees estimate total potash demand in these 15 States at 31,000 tons in 1955 to meet attainable levels of agricultural production. For the country as a whole, however, potash consumption is estimated to increase by 835,000 tons or 77 percent between 1950 and 1955.

If it is desired to add potash as a fertilizer ingredient in the proposed production plan in order to permit meeting demands for potash-containing mixtures, principally in more distant markets, the appropriate mixing equipment could be added with little extra investment. There are available near Green River, in the vicinity of the soda ash deposits at Westvaco, Wyo., large reserves of potash minerals (Wyomingite) containing about 11 percent K_2O [the unit of measurement for potash].

While commercial development of these reserves, which are estimated to contain upward of 1 billion tons of Wyomingite, has not yet been attained, active study is being given to the economic feasibility of obtaining a potash suitable for fertilizer by treating Wyomingite with soda ash, utilizing the base exchange principle. Engineering authorities have stated that with the close juxtaposition of soda ash and Wyomingite, and with process water, fuel, and rail transportation close at hand, the outlook for the development of these deposits seems bright.

Products to be manufactured

To provide maximum flexibility in product mix, the capacity of the plant might range from 80,000 to 125,000 tons annually, depending upon the type of fertilizer material manufactured. The key materials to be produced are phosphatic fertilizers—a substantial part of which would be nitrophosphates (TVA)—and ammonium sulfate.

Various alternatives as to product combinations are given in table 1. If 10,000 tons of ammonium sulfate are produced instead of 5,000 tons, thus requiring more of the ammonia and sulfuric acid, less of these materials would be available to make the nitrophosphates and superphosphates, and the output of the latter would be correspondingly reduced. Similarly, the quantity of superphosphates produced would depend largely upon the degree of concentration desired. If the same amount of acid is used to produce concentrated superphosphate instead of ordinary superphosphate, a smaller quantity of material would result, and vice versa.

TABLE 1.—*Annual production capacity*

[Tons]

Product	Alternative 1		Alternative 2	
	A. Assuming all nonammoniated superphosphates are concentrated	B. Assuming all nonammoniated superphosphates are ordinary	A. Assuming all nonammoniated superphosphates are concentrated	B. Assuming all nonammoniated superphosphates are ordinary
Ammonium sulfate	5,000	5,000	10,000	10,000
Nitrophosphates (TVA)	60,000	60,000	50,000	50,000
Other superphosphates:				
Concentrated	25,000		20,000	
Ordinary		60,000		50,000
Total	90,000	125,000	80,000	110,000

The proposed range of product mix would have the following advantages:

1. It would provide a flexible combination of regular and premium fertilizers for particular markets. Production could be

readily shifted to or from one product or another. Initially, greater emphasis might well be placed upon the concentrated superphosphate than upon ordinary superphosphate in order to maximize freight advantages in supplying the midwestern markets. Over the longer run, as demand in Wyoming and other Western States increases, larger amounts of ordinary superphosphate might be produced.

2. It would help meet the requirements of specific soils for fertilizers containing either or both of two basic plant foods—phosphorus and nitrogen. Nitrophosphates (containing both nitrogen and phosphorus) would be available for certain soils, and ordinary and concentrated superphosphates (containing phosphorus alone) for other soils, depending upon local soil conditions.

3. It would make available a substantial tonnage of ammonium sulfate which is especially required for the alkaline soils of Wyoming and neighboring States. This material is in Nation-wide short supply. Very little is now produced in the mountain area.

4. It would permit use of lower grade rock.

5. It would permit significant savings in investment, production, and transportation costs.

IV. Factors Essential to Production

To support an active fertilizer industry, the following essentials are required: (1) Availability of raw materials, fuel, and power; (2) availability of transportation; (3) adequacy of markets; (4) competitive costs.

These factors are reviewed briefly below with respect to a possible fertilizer plant in Wyoming.

Raw materials, fuel, and power

Wyoming is favorably situated with respect to the raw materials, fuel, and power required to produce phosphatic fertilizers by the wet process. The basic raw materials required are phosphate rock and sulfur.

Phosphate rock.—Substantial deposits of phosphate rock estimated at upward of 150 million tons of varying grades are located in Wyoming. This figure may be too low since areas known to contain phosphate rock remain to be thoroughly surveyed.

Those deposits in the western part of the State have the advantage of being higher grade while those in the central part of the State are more extensive and are advantageously situated with respect to nearness to existing markets. As in the case of the other Western States, the major share of the phosphate rock deposits is located on public lands.

Production of phosphate rock in Wyoming is currently roughly estimated at 200,000 tons annually, and has been increasing steadily. Development to date has centered around Sage and Kemmerer in Lincoln County, and Lander in Fremont County.

Sulfur.—For the integrated production operation outlined above, about 10,000 tons of sulfur would be required per year. This can be supplied entirely by sources within the State.

In the last 3 years alone, numerous new sources of sulfur have been developed in Wyoming and are in production; others are under way.

The Texas Gulf Sulphur plant at Worland, Wyo., manufacturing sulfur from natural gas, was brought into production in 1950, with a capacity of 100,000 tons a year. The Stanolind Oil plant at Elk Basin, Wyo., began operations in 1949, with capacity of 23,000 tons of sulfur per year from natural gas. General Petroleum was recently granted a necessity certificate for a plant to produce 20,000 tons of sulfur yearly at Worland, from oil and gas from the Manderson and Slick Creek fields. The Defense Minerals Exploration Administration recently announced discovery of a large sulfur deposit in Park County, Wyo., with production estimated at 10,000 tons annually. A new operation, conducted by Wyoming Gulf Sulphur, producing sulfur concentrates from extensive surface deposits near Cody, Wyo., came into production a few months ago, and is producing at the rate of 12,000 tons annually.

Other projects involving the recovery of sulfur from sour gas are considered "probable," including one at Silvertip, Wyo., which would call for sulfur production of 35,000 tons annually.

Although it is estimated from the above that the required sulfur will be available, if desired, the proposed integrated fertilizer plan would provide its own sulfur. This is to be done by including, at a relatively small investment, a sulfur recovery plant suitable for manufacturing sulfur from the hydrogen sulfide contained in sour gas, of which ample quantities are available at various wells and refineries in the State. This sulfur would then be used to manufacture the sulfuric acid needed to operate the fertilizer plant.

Fuel and power

Natural gas is available in ample quantities to meet at favorable rates all requirements of the projected fertilizer plant for fuel, and as a source of hydrogen. The wet process requires relatively small quantities of power, chiefly for rock grinding. Estimates indicate a total requirement of 150 to 250 kilowatt-hours per ton of fertilizer produced. It is estimated that power in these quantities will be available without difficulty as needed.

Transportation facilities

The key factors affecting selection of a site for the projected fertilizer plants are the location of the phosphate rock and the sulfur source. Whether one location or the other is used as a site for the fertilizer plant is a matter of close calculation as to comparative costs. Ordinarily, it is considered more economic to move phosphate rock than to move sulfuric acid, and more economic to move sulfur than to move rock.

In either case, however, adequate rail transportation is available. Cody and Worland, for example, where substantial amounts of sulfur are produced, are on the Chicago, Burlington & Quincy Railroad, while the phosphate deposits of central Wyoming extend around the junction of the Chicago, Burlington & Quincy and the Chicago & Northwestern Railroad. To carry the example further, Worland, where sulfur is now produced at the rate of 100,000 tons a year, is only about 100 miles on the Chicago, Burlington & Quincy from Lander, where large phosphate rock deposits exist. Similarly, the deposits being developed in Lincoln County are located on the Union Pacific rail line, which runs east and west across the State.

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Rail lines and connections to the rich markets of the Midwest and west coast are favorable.

Markets

A consideration of prospective markets must be based upon the outlook for fertilizer demand over the next few years in the broad areas in which Wyoming fertilizer would be competitive, as well as upon potential increased use of fertilizer in prospect for Wyoming and other Western States, particularly for pasture land.

The use of fertilizers in the United States has been climbing steeply for some time. All factors point to continued substantial increases. In the last 10 years alone, it has more than doubled. In the case of phosphatic fertilizers, consumption has been as follows, expressed in terms of the unit of plant food, phosphorus pentoxide (P_2O_5):

	Tons
1932	450,000
1942	1,100,000
1952 (estimated)	2,200,000

Despite the enormous growth, it is estimated that perhaps 75 percent of the cropland of the United States, and 95 percent of the grassland, still receive no fertilizer, indicating the extent of the potential market which still remains untapped.

Requirements for domestic use in 1955 are estimated by the Department of Agriculture at 3.2 million tons of P_2O_5, and requirements for 1960 at 3.6 million tons. Superphosphate fertilizers supply over 90 percent of the available phosphate used in the United States. Ordinary superphosphates contain up to about 20 percent P_2O_5, while concentrated or triple superphosphates contain up to about 48 percent P_2O_5.

INCREASE TENFOLD

A 17-State area west of Chicago is frequently defined as the most favorable economic area for western phosphates on the basis of competitive supply and transportation costs.[1] In this area, consumption of phosphate fertilizer in 1950 was about 350,000 tons; present consumption totals over 400,000 tons per year, about 10 times prewar annual consumption. Requirements for 1955 in this area are estimated at a total of about 630,000 tons of P_2O_5.

In the Mountain States alone, requirements for 1955 are estimated at about 79,000 tons as against actual consumption of 49,000 tons in 1950.

Significantly, nitrogen requirements for the 17-State area are placed at about 525,000 tons in 1955, as against consumption of 232,000 in 1950. Nitrogen would be contained in the nitrophosphates (TVA) to be produced in the proposed fertilizer plant.

To view the long-range market outlook from another standpoint, it has been estimated that despite the high current rates of use, there is a net annual loss of upwards of 3 million tons of P_2O_5 from the soils of the United States, due to harvesting and grazing. The net depletion of phosphorus from the soils of the 17-State area alone is estimated at approximately 900,000 tons per year, thus augmenting already existing needs.

[1] Includes northern Illinois, Iowa, Wisconsin, Minnesota, Kansas, Nebraska, North Dakota, South Dakota, Montana, Wyoming, Colorado, Utah, Idaho, Nevada, Washington, Oregon, and California. Also parts of Arizona and Missouri.

At a meeting held on October 7, 1952, of the Phosphatic Fertilizer Industry Advisory Committee of the National Production Authority, made up of representatives of the industry, the demand outlook as summarized by the committee and released by the NPA was as follows:

> Domestic demand for phosphatic fertilizers is expected to increase at a rate of about 7½ percent per year. At this rate of growth, demand for the calendar year 1953 would amount to between 2.5 and 2.6 million tons of P_2O_5. Growth in the traditional heavy-consuming area east of the Appalachian Mountains would not exceed 5 percent; but growth in the central Plains and west-coast areas might well exceed 10 percent. Demand for concentrated superphosphates is increasing at a very rapid rate, and there should be a ready market for the 150 percent increase (approximately 1 million tons) in production of this commodity, especially in the central Plains area.

The extensive program of new irrigation planned for the West will also serve to expand prospective markets for fertilizer. As land is reclaimed, considerable fertilizer application will be needed to build up its full production potentialities. This is especially true for pasture land. It has been demonstrated that the proper use of fertilizer on land receiving sufficient water will increase enormously the animal population which can be sustained on that land. At the same time, increased crop and forage production made possible by irrigation will accelerate depletion of phosphorous from the soil unless adequate amounts of phosphatic fertilizers are continually supplied.

Competitive costs

The proposed plant would incorporate the latest advances in acidulation technology, permitting a range of phosphoric and nitrogenous fertilizer product blends and combinations not now available from any single plant in the United States. The emphasis on flexibility of the products manufactured to meet the needs of particular markets is a highly important competitive factor. This flexibility is of three general types: (1) Ammoniated versus nonammoniated fertilizers; (2) concentrated versus ordinary superphosphates; (3) superphosphates versus ammonium sulfate.

The nature and extent of the planned integration would provide further cost economies on a scale not enjoyed by any existing producer. Of particular significance are the savings resulting from self-sufficiency in acid and the use of the ammoniation process. Even if the cost of new phosphate rock should be somewhat higher than that produced elsewhere in the country because of the grade or depth of deposits being worked, this difference should be well within the margin of other savings.

Freight advantages within the 17-State area would provide a further competitive gain in relation to fertilizer originating from Florida or Tennessee rock. This means that the potential market for a Wyoming plant consists not only of the projected increase in fertilizer demand in the 17-State area, but also of some share of the existing market in this area.

The important potential byproducts resulting from the acidulation of phosphate rock should also be noted. These byproducts include uranium, vanadium, and fluorides. Aside from their importance as contributions to atomic energy, strategic stockpiling, and public health programs, these products have significant economic value.

NEW PLANTS FOR THE WEST

With raw materials and transportation readily available, and with large and growing markets lying close at hand, the growth of a western fertilizer industry of major proportions appears inevitable. This industry in the West is on the verge of a great new development which will go far beyond the important beginnings which have already been made.

Recently Stauffer Chemical Co. announced plans for a new superphosphate plant of 60,000 tons capacity to be located near Salt Lake City, using phosphate rock from Idaho and Wyoming and manufacturing its own sulfuric acid from sulfur recovered from smelter gases. Allied Chemical and Dye Corp., one of the major chemical companies in the country and the largest producer of nitrogen, submitted on October 22, 1952, to the Defense Production Administration a new proposal for a $27 million integrated fertilizer plant to make 200,000 tons of nitrophosphates per year (containing 30,000 tons of P_2O_5 and 30,000 tons of nitrogen) plus other fertilizers, using a process similar to that developed by TVA. This plant, located at Pasco, Wash., would be the largest fertilizer plant in the Northwest. Allied Chemical has also submitted another proposal for a similar plant of the same size and type to be located at La Platte, near Omaha, Nebr.; this would be in addition to the $25 million nitrogen plant already under way at that site. Other projects are also under consideration.

At the present incipient stage of development, a great deal can be done to influence the location of new plants, and to encourage the development of the industry along lines which would be peculiarly advantageous to the West, in contrast with the type of development which has taken place in older centers of fertilizer production. Specifically, the construction of large integrated plants of the type outlined in this paper appears to provide the most economic means of making available cheap abundant fertilizer materials which would contribute much to more and better land use in the West.

USE OF SODA ASH

Special mention should be made of a process for producing phosphate fertilizer which, from a long-range standpoint, holds great promise for future resource development for the West in general and for Wyoming in particular. In this process, which has been in successful commercial operation in Germany for many years, a mixture of phosphate rock, sand, and soda ash is treated in a rotary kiln to produce phosphate fertilizers.

One of the richest deposits of natural soda ash in the world is located at Westvaco, Wyo. The known resources are approximately 250 million tons, while the full extent of the Wyoming deposits are estimated to run into the billions of tons. A new $20 million plant of the Intermountain Chemical Corp. at Westvaco for producing 300,000 tons of soda ash annually was approved for tax amortization by the Defense Production Administration recently.

A new plant utilizing soda ash to make phosphate fertilizer in a manner similar to the German process is about to go into production at Kemmerer, Wyo. This plant, operated by Phosphate Mines, Inc., expects to produce at the rate of about 30,000 tons per year. The phosphate rock is to come initially from deposits operated in the

vicinity of Sage, Wyo., by the San Francisco Chemical Co., although eventually Phosphate Mines, Inc., plans to mine its own phosphate rock from high-grade deposits located near Kemmerer. The soda ash used in this operation is being provided by the Intermountain Chemical Corp. plant at Westvaco.

Active study as to the economic possibilities of this process is also being given by various other companies, including major producers of soda ash. Meanwhile, field tests are being carried on by Federal and State agricultural authorities to determine the specific suitability of phosphates made by this process to western soil conditions.

V. Federal and State Cooperation

There is much that can be done at both State and Federal levels to promote increased fertilizer production and use in the West. Among the constructive steps to be taken, the following may be mentioned:

State activities

1. Initiate active program to survey most feasible locations for fertilizer plant sites, and to interest potential producers.
2. Review short-range and long-range needs in each State of particular fertilizer materials based upon specific soil conditions so as to assure that these needs are considered in type of plants built.
3. Disseminate more actively information concerning economics of using fertilizer materials, particularly on pasture lands.
4. Cooperate with the Federal Government in studying ways and means of improving availability of credit to farmers to finance fertilizer needs.
5. Continue joint studies with each other and with the Federal Government concerning fertilizer industry potentialities, markets, raw materials, and technologies. (One such study is now in process by a task force of the Columbia Basin Inter-Agency Committee.)

Federal activities

1. Provide appropriate financial assistance.

(*a*) *Tax amortization.*—The Government has established an expansion goal for production of phosphate fertilizers. This goal calls for domestic production capacity of 3,550,000 tons of P_2O_5 by July 1, 1954—an expansion of 1,500,000 tons over existing capacity—and has not yet been filled. The Defense Production Administration has stated that tax amortization will be granted to eligible projects undertaking to manufacture phosphate fertilizers to meet this goal. Especially attractive incentives are being offered to producers planning to manufacture nitrophosphate fertilizers, as indicated by the fact that on September 10, 1952, the Defense Production Administration announced the granting of a tax amortization certificate of 75 percent to the Allied Chemical & Dye Corp. for construction of a $6 million plant at South Point, Ohio, to make nitrophosphates by a process similar to that described in this report. On October 1, 1952, a tax-amortization certificate was granted to the Gulf Improvement Co. for a $15 million plant at Pascagoula, Miss., to make nitrophosphates by still another process of this type; this certificate was for a rate of 45 percent to be applied to the ammonia facilities and a rate of 80 percent to be applied to the balance of the plant. In each case, the percentage certified

under tax amortization refers to the share of the investment cost which may be written off over a 5-year period for tax purposes. Presumably, other producers undertaking such plants would receive corresponding consideration. Among the applications pending at the present time are two recently submitted by Allied Chemical and Dye Corp., each providing for a new $27 million plant with an annual capacity of 200,000 tons of nitrophosphate fertilizers in addition to other fertilizer materials; one plant is to be located at Pasco, Wash., and one at La Platte, Nebr.

(*b*) *Loans and guaranties.*—These are authorized under title III of the Defense Production Act of 1950, as amended, for materials requiring expansion of capacity, where financing is not otherwise available on reasonable terms. It might be desirable for the Government, without committing itself to any specific project or locality, to establish a policy as to the conditions under which loans and guaranties might be considered for construction of new fertilizer plants, where the attainment of defense expansion goals is not otherwise feasible.

2. Consider possible liberalization of terms for leasing public lands containing phosphate rock, particularly where rock is of lower grade or at greater depths than elsewhere.

3. Press further research into techniques and economies of using various combinations of fertilizer materials on pasture lands.

4. Develop specific proposals for expanding provision of credit needed by farmers to help finance fertilizer purchases.

5. Sponsor comprehensive programs of investigation into economic considerations affecting expansion of the fertilizer industry in the Western States. These studies should be developed in cooperation with all the producing and consuming States affected.

In this connection, special note should be taken of the constructive program of research, education, organization, and facilitating activities recently announced jointly by the Association of Land-Grant Colleges and Universities and the Department of Agriculture, under the title "A National Program for More Efficient Use of Fertilizer and Lime." The program advanced is as follows:

PROGRAM NEEDED

How to utilize fertilizer and lime most effectively to accomplish the objectives of increasing food and fiber production, building up the productive capacity of the Nation's farm plant, and increasing net incomes to farmers is a problem of concern to farmers, Government, private industry, and the public. This problem requires careful study and planning by all segments of agriculture in order that the best fertilization practices may be fitted into an over-all farming system which will provide for the production of those agricultural products most needed by the people.

The Department and the land-grant colleges and universities have a joint responsibility for promoting the efficient and proper use of fertilizer and lime. Eventual optimum use of fertilizer and lime will require an expanded long-range program of research, education, and other services. The immediate problem, however, is the need to help farmers achieve the best possible results from the increased supplies of fertilizer and liming materials which will be available in the next few years.

This will require a joint, coordinated effort on the part of the United States Department of Agriculture and the land-grant colleges in cooperation with the fertilizer and lime industries, and other public and private organizations.

RESEARCH

The research being carried on by the land-grant colleges, the Department, the Tennessee Valley Authority, and private organizations in connection with fertilizer, soil, and crop production is contributing to attainment of the program objectives. Special emphasis, however, should be given to the following:

1. Fertilizer technology

Investigate means of overcoming the limiting effect on fertilizer production of the sulfuric-acid shortage. This will include studies aimed at developing economical processes that require less sulfuric acid or entirely dispense with its use in the production of phosphates and nitrogenous materials. Full support will continue to be given to measures aimed at the more complete utilization of byproduct sources of sulfuric acid, such as smelter fumes in the West and other sections of the country.

There is also need for extensive research on the production of high-analysis mixed fertilizers having improved physical condition and suitable for year-round storage under both factory and farm conditions.

The additional materials to be produced under the expanded fertilizer-production program will have an average plant-nutrient content (N, P_2O_5, K_2O) of approximately 44 percent, as compared with an average plant-nutrient content of 24 percent in mixed fertilizers presently produced. There is particular need for research to develop methods of processing these high-analysis materials whereby the most economical and efficient types and grades of mixed fertilizers will be produced.

2. Marketing of fertilizer and lime

Study methods of fertilizer and lime distribution and marketing with a view to reducing the cost between the producer and the consumer. Special attention should be given (1) to studies of the bulk distribution of fertilizer directly to the farm, including fertilizer materials and mixtures, with particular reference to distribution costs and the possible savings to the consumer that might be effected thereby; (2) to the relation of the plant-nutrient concentration of fertilizer to the farm cost of such nutrients; and (3) to problems of packaging and warehousing so that materials can be satisfactorily stored during the off season.

3. Methods of fertilizer and lime application

Research workers in industry and in government, cooperating through the National Joint Committee on Fertilizer Application, have made distinctive contributions in the field of fertilizer application. Some additional needs for advancing fertilizer application practices in the future include—

(*a*) Research and discussions to develop more uniform agreement as to proper fertilizer placement so equipment manufacturers can proceed with the design and production of special equipment adapted to wider areas. Included in these needs are equipment for liming and fertilizing subsoils, machines for precision placement of fertilizer at variable points in relation to seed location and drills for handling new types of materials.

(*b*) Research on economical equipment for distributing new types of fertilizer materials including liquids and compressed gasses.

(*c*) Research on the application of larger amounts of fertilizer by side-placement to save extra application operations.

(*d*) Development of equipment and procedures for fertilizer and lime application on small farms where farm machinery overhead costs must be low.

(*e*) Research on fertilizer distribution by aircraft.

4. Soils and plant analysis

Further research is needed to increase precision in determining fertilizer needs based upon analyses of soils and plants.

5. Physical response and economic levels of use

Economic interpretation of response to fertilizers requires knowledge of the full length and shape of the response curve. Therefore, data on response to a single variable nutrient in the presence of different levels of other nutrients are needed to furnish the physical basis on which economic interpretation must rest. The different rates used in experimental work conducted for this purpose should cover a wide range, including rates at which no appreciable increases in yields are obtained.

Along with adequate crop-response data, information also is needed on (*a*) the response and relative cost of elements from different sources and (*b*) the costs of applying a given amount of plant food by different methods as well as in different forms. Moreover, information is needed on the contribution and role of fertilizer in a complete cropping rotation or sequence as it relates to cropping practices and livestock production on the farm as a management unit.

Data showing increments in yields associated with each additional unit of application permit determination of the most profitable rates for farmers in different positions with reference to available capital and tenure status. The farmer with limited funds must plan his expenditures not only with reference to the quantity of fertilizer applied but also must determine the most profitable combination of fertilizer and other farm resources. Furthermore, this combination is influenced by the tenure arrangement—how the costs and returns are divided.

6. Evaluation of unexhausted soil improvements

Further study is needed in connection with the evaluation of unexhausted resources added to the soil, particularly as related to the problem of tenure arrangements, so that guides can be provided for the equitable division of costs and returns between owners and tenants and reimbursement of a vacating tenant for the improvements he has made.

7. Statistics

Adequate statistical information concerning use of fertilizers is essential to any accurate appraisal of a current situation or developing trends in usage. Steps should be taken to encourage collection of such data in areas where no statistical report is now being made, and to expand those now being made to give more information concerning fertilizer usage on different soils and crops.

Special periodic surveys of use of fertilizer and lime by farmers should be made in order to obtain information as to applications on different crops by areas and other information concerning particular problems. To accompany such surveys, there is much to be gained by making, in a systematic manner, periodic inventories of the nutrient-level status of soils in order to evaluate the fertility trends resulting from current cropping practices and fertilizer usage.

EDUCATION

The Department will be responsible for (*a*) assembling materials of national and regional application and usefulness, (*b*) enlisting the help of interested national organizations in a position to add impetus and to contribute to the program, and (*c*) encouraging the participation of the radio, farm, press, and other nationally organized public media which can contribute significantly to the success of the program.

Within the States, leadership in the educational program will be the responsibility of the Cooperative Agricultural Extension Service as the educational arm of the Department and the land-grant colleges.

Participation of other groups

In planning and carrying out the educational program the Cooperative Agricultural Extension Service will solicit the active participation of agricultural mobilization committees and other interested persons and organizations, including fertilizer and equipment dealers and distributors, bankers, and farm organizations.

Activities requiring special emphasis

It is contemplated that, in conducting the educational program, full use will be made of all established channels for reaching farmers and other interested parties. In addition to the educational activities now in progress, special emphasis will need to be placed on the following:

1. *Preparation and dissemination of information.*—The preparation and dissemination of information designed to assist farmers in making optimum use of fertilizer and lime on their own farms.

2. *Additional demonstrations.*—Additional demonstrations of fertilizer and lime use on individual farms to emphasize local adaptations of recommended practices.

3. *Soil and plant tests.*—Use of soil and plant tests to (*a*) stimulate interest in proper plant nutrition, and (*b*) aid in the determination of lime and fertilizer needs on the individual farms.

4. *Economics of crop response.*—Design of educational materials so as to provide in simplified form the economic interpretation of crop response to fertilizer

and lime use and related practices. Such information will need to take into account the requirements of each individual crop as grown on different soils and under different farming situations so as to contribute most to development of a balanced fertilizer program for the farm as a unit.

5. *Financing soil improvement.*—Carrying educational work to both farmers and lenders which will demonstrate the soundness of credit for financing soil improvements and other productive investments, and will indicate how additional returns may be used for repayment of loans.

OTHER FACILITATING ACTIVITIES

Certain activities in addition to those in the fields of research and education can contribute substantially to a balanced program for efficient and profitable utilization of fertilizer and lime. Such activities include—

Technical and financial assistance

1. Technical and financial assistance to farmers and ranchers in developing and executing their individual farm plans, taking into consideration the capabilities of the soil, systems of farming, good farming practices, and the availability of labor, equipment, and capital, and assistance in carrying out approved soil- and water-conservation practices.

Credit

2. Making it possible for farmers to obtain credit as needed to purchase appropriate kinds and amounts of fertilizer and lime for balanced systems of farming, including, where necessary, loans by Government agencies to eligible farmers who are unable to obtain adequate credit from banks and other private lenders.

Leasing arrangements

3. Aid in developing leasing arrangements which provide for equitable sharing of costs and returns, thereby creating tenure situations which are conducive to the use of most profitable quantities of fertilizer and lime.

ORGANIZATION

1. A steering committee representing the Department and the land-grant colleges will serve at the national level in guiding programs in connection with utilization of fertilizer and lime toward the objective of optimum results in terms of yields of needed crops, soil improvement, and farm income.

2. Within the States and counties leadership will be the responsibility of the land-grant colleges working with local representatives of other interested State and Federal agricultural agencies and private groups.

3. The National Soil and Fertilizer Research Committee will take steps to encourage appropriate State agricultural workers to interpret and prepare for dissemination, in a form suitable for educational purposes, the available data on crop response to increments of plant nutrients and lime and profitable levels of use under different conditions.

4. The continuing cooperation of the fertilizer and lime industries and other interests is invited to the end that industry activities will be coordinated with the national fertilizer and lime-utilization program.

5. The continued collaboration and participation of the State fertilizer-control officials and the Tennessee Valley Authority will contribute substantially to the success of the program.

TABLE A.—*Quantities of plant nutrients used in 1950 and estimated quantities needed for level and pattern of production attainable by 1955*

Region	Used in 1950	Needed in 1955	Percentage increase	Used in 1950	Needed in 1955	Percentage increase
	Nitrogen (N)			Phosphoric acid (P_2O_5)		
	1,000 tons	*1,000 tons*	*Percent*	*1,000 tons*	*1,000 tons*	*Percent*
Northeast	91.8	136.3	49	277.6	392.3	41
Corn Belt	114.6	394.0	244	550.0	888.7	62
Lake States	28.7	73.6	157	153.9	261.8	70
Appalachian	166.4	233.8	41	376.3	504.8	34
Southeast	219.6	360.4	64	342.0	470.6	38
Mississippi Delta	153.8	264.1	72	107.1	203.3	90
Southern Plains	33.6	94.5	181	108.9	190.6	75
Northern Plains	30.7	129.7	322	43.3	100.0	131
Mountain	36.5	68.6	88	49.1	78.9	61
Pacific	150.3	222.3	48	80.2	129.8	62
United States	1,026.0	1,977.3	93	2,088.4	3,220.8	54
	Potash (K_2O)			Total nutrients		
Northeast	162.7	291.3	79	532.1	820.0	54
Corn Belt	268.3	500.3	87	932.9	1,783.1	91
Lake States	111.6	217.9	95	294.2	553.3	88
Appalachian	208.4	348.5	67	751.0	1,087.1	45
Southeast	232.3	390.0	68	793.9	1,221.0	54
Mississippi Delta	59.4	110.7	86	320.4	578.1	80
Southern Plains	14.9	26.4	78	157.4	311.5	98
Northern Plains	3.3	6.1	85	77.3	235.7	205
Mountain	2.8	2.9	2	88.4	150.3	70
Pacific	18.2	22.0	21	248.7	374.1	50
United States	1,081.9	1,916.1	77	4,196.3	7,114.2	70

Source: Agriculture's Capacity to Produce: Possibilities Under Specified Conditions, Agriculture Information Bulletin No. 88, U. S. Department of Agriculture, June 1952, table 15.

TABLE B.—*Estimated quantities of plant nutrients used on specified crops in 1950, and estimated quantities needed for use on these crops by 1955 in States reporting fertilizer use by crops* [1]

Crop and pasture	Used in 1950	Needed by 1955	Used in 1950	Needed by 1955
	Nitrogen (N)		Phosphoric acid (P_2O_5)	
	Tons	*Tons*	*Tons*	*Tons*
Cotton	161,316	255,201	133,806	202,650
Tobacco	32,861	39,066	72,876	81,961
Potatoes	34,470	36,862	52,724	59,878
Sugar beets	5,467	6,950	11,988	14,030
Peanuts	3,840	7,211	17,019	26,463
Dry beans	703	875	5,248	6,520
Soybeans	1,539	2,636	17,058	52,017
Wheat	63,981	184,669	176,895	295,207
Corn	267,815	646,193	440,513	617,232
Sorghums	3,059	6,127	3,158	5,183
Oats	53,755	134,397	116,399	221,091
All tame hay and pasture	47,946	122,196	358,750	681,710
Rotation pasture [2]	(7,596)	(26,412)	(74,329)	(134,270)
Permanent pasture [2]	(7,099)	(36,727)	(57,809)	(137,820)
All specified crops and pasture	676,752	1,442,383	1,406,434	2,263,942
	Potash (K_2O)		All nutrients	
Cotton	88,594	165,717	383,716	623,568
Tobacco	59,726	77,413	165,463	198,440
Potatoes	49,901	60,207	137,095	156,947
Sugar beets	3,327	3,960	20,782	24,940
Peanuts	12,151	31,633	33,010	65,307
Dry beans	2,550	3,186	8,501	10,581
Soybeans	13,313	43,143	31,910	97,796
Wheat	105,447	151,627	346,323	631,503
Corn	289,224	433,454	997,552	1,696,879
Sorghums	1,261	3,156	7,478	14,466
Oats	76,673	145,470	246,827	500,958
All tame hay and pasture	120,798	416,340	527,494	1,220,246
Rotation pasture [2]	(28,613)	(88,437)	(110,538)	(249,119)
Permanent pasture [2]	(18,977)	(73,972)	(83,885)	(248,519)
All specified crops and pasture	822,965	1,535,306	2,906,151	5,241,631

[1] See table E for acreage of each crop included in States reporting fertilizer use, by crops.
[2] Included under "All tame hay and pasture."

Source: Agriculture's Capacity to Produce Possibilities Under Specified Conditions, Agriculture Information Bulletin No. 88, U. S. Department of Agriculture, June 1952, table 16.

TABLE C.—*Estimated acreage and percentage of acreage of specified crops fertilized in 1950, in States reporting, and estimated acreage and percentage of acreage on which applications may be attained by 1955*

Crops and pasture	Percentage of United States acreage in States reporting [1]		Acreage and percentage of acreage fertilized in States reporting				Increase in acreage on which use of fertilizer is attainable
			Adopted 1950		Attainable 1955		
	1950	Estimated 1955	Acreage	Percentage of total	Acreage	Percentage of total	
	Percent	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*Percent*
Cotton	96.0	94.6	10,056	56.2	12,430	54.4	24
Tobacco	100.0	99.9	1,564	97.8	1,809	97.6	16
Potatoes	82.2	86.6	1,051	74.6	1,089	82.1	4
Sugar beets	66.1	70.9	479	70.8	536	80.5	12
Peanuts	99.1	99.3	1,524	56.0	2,106	75.1	38
Soybeans	75.7	74.8	1,378	12.0	3,560	32.2	158
Wheat	89.1	90.9	12,809	20.2	20,798	29.4	62
Corn	96.4	99.1	38,058	47.7	49,156	60.1	29
Sorghums	87.9	88.0	280	2.0	444	3.6	59
Oats	85.0	89.6	11,490	29.7	17,397	44.6	51
All tame hay and pasture	89.5	89.6	19,774	3.8	34,288	6.4	73
Rotation pasture	30.7	[2] 32.3	(4,150)	[2] 24.7	(6,691)	36.0	61
Permanent pasture	29.3	[2] 40.2	(2,749)	[2] 1.5	(6,771)	3.5	146
All specified crops and pasture	89.8	90.5	98,463	13.0	143,613	18.4	45

[1] Includes most of the acreage upon which a significant quantity of fertilizer is used. A few States either did not report use of fertilizer on minor crops or they reported it on a group of crops that could not be segregated.

[2] Also included under "All tame hay and pasture."

Source: Agriculture's Capacity to Produce: Possibilities Under Specified Conditions, Agriculture Information Bulletin No. 88, U. S. Department of Agriculture, June 1952, table 17.

TABLE D.—*Estimated rates of application per acre of specified crops in 1950 and estimated rates attainable and profitable for these crops by 1955, in States reporting fertilizer use by crops*

Crop and pasture	Used in 1950	Needed in 1955	Used in 1950	Needed in 1955
	Nitrogen (N)[1]		Phosphoric acid (P_2O_5)[1]	
	Pounds	*Pounds*	*Pounds*	*Pounds*
Cotton	32.1	41.1	26.6	32.6
Tobacco	42.0	43.2	93.3	91.0
Potatoes	66.6	67.6	100.1	110.0
Sugar beets	22.8	25.9	50.0	52.4
Peanuts	5.1	6.8	22.3	25.1
Dry beans	3.3	4.6	24.3	36.3
Soybeans	2.2	1.4	24.8	29.2
Wheat	10.0	17.8	27.6	28.4
Corn	14.1	26.3	23.1	25.1
Sorghums	21.9	27.6	22.6	23.4
Oats	9.4	15.4	20.3	25.4
All tame hay and pasture	4.8	7.1	36.2	38.8
Rotation pasture[2]	3.7	7.9	36.0	40.1
Permanent pasture[2]	5.2	6.8	42.0	38.4
Average, specified crops and pasture	13.7	20.0	28.3	31.4
	Potash (K_2O)[1]		All nutrients	
Cotton	17.6	26.7	76.3	100.4
Tobacco	76.4	86.6	211.7	219.8
Potatoes	95.0	110.6	261.7	288.2
Sugar beets	13.9	14.8	86.7	93.1
Peanuts	15.9	30.0	43.3	61.9
Dry beans	11.8	17.7	39.4	58.6
Soybeans	19.3	24.2	46.3	54.8
Wheat	16.5	14.6	54.1	60.8
Corn	15.2	17.8	52.4	69.2
Sorghums	9.0	14.2	53.5	65.2
Oats	13.3	16.7	43.0	57.5
All tame hay and pasture	12.2	24.3	53.2	70.2
Rotation pasture[2]	13.8	26.4	53.5	74.4
Permanent pasture[2]	13.8	24.3	61.0	69.5
Average, specified crops and pasture	16.6	21.2	58.6	72.6

[1] Estimated quantity of each nutrient divided by estimated acreage receiving any fertilizer.
[2] Also included under "All tame hay and pasture."

Source: Agriculture's Capacity to Produce: Possibilities Under Specified Conditions, Agriculture Information Bulletin No. 88, U. S. Department of Agriculture, June 1952, table 18.

TABLE E.—*Estimates of the use of fertilizer nutrients (N, P_2O_5 and K_2O) by major crops and regions, 1950 and attainable by 1955, in States reporting fertilizer use by crops*

Region	Cotton		Tobacco		Potatoes		Wheat		Soybeans		Corn		Oats		All tame hay and pasture	
	1950	1955	1950	1955	1950	1955	1950	1955	1950	1955	1950	1955	1950	1955	1950	1955
	Percent															
Percentage of acreage reported treated:																
Northeast	----	----	100	100	100	100	86	91	61	74	90	98	64	70	24	30
Corn Belt and Lake States	60	80	84	85	62	80	76	79	7	25	57	64	33	51	7	13
Appalachian	90	92	98	97	96	99	86	89	41	68	63	76	75	76	22	33
Southeast	100	100	100	100	82	85	94	96	34	67	91	100	85	92	16	27
Mississippi Delta	87	93	----	----	95	97	58	86	19	48	72	89	72	88	9	19
Southern Plains	15	16	----	----	66	100	4	15	----	----	22	47	7	17	2	3
Northern Plains	----	----	----	----	35	44	12	21	4	3	5	15	5	34	(1)	2
Mountain and Pacific	73	79	----	----	78	83	3	14	----	----	7	30	5	8	1	1
	Pounds															
Plant nutrient application per acre:																
Northeast	----	----	255	303	425	505	88	100	42	115	68	81	45	78	59	105
Corn Belt and Lake States	(1)	100	159	268	202	179	61	78	46	51	50	68	40	53	35	79
Appalachian	99	143	199	198	245	325	57	76	56	62	63	82	57	70	51	65
Southeast	99	131	264	288	319	341	58	98	40	45	47	77	46	98	75	72
Mississippi Delta	66	81	----	----	108	140	80	99	32	33	41	73	52	56	70	74
Southern Plains	34	48	----	----	96	111	30	30	----	----	42	61	39	36	50	51
Northern Plains	----	----	----	----	42	43	32	41	10	10	31	41	28	52	31	34
Mountain and Pacific	96	106	----	----	141	159	38	33	----	----	55	38	41	62	62	64

[1] Not reported.

Source: Agriculture's Capacity to Produce: Possibilities Under Specified Conditions, Agriculture Information Bulletin No. 88, U. S. Department of Agriculture, June 1952, table 19.

PART 2

STAMFORD, CONN., *October 1952.*

PROPOSED MANUFACTURE OF COMPLETE CONCENTRATED FERTILIZER MIXTURES AT GREEN RIVER, WYOMING, UTILIZING POTASH PRODUCED BY BASE EXCHANGE FROM WYOMINGITE

By Robert D. Pike, consulting chemical engineer

This paper will present a brief analysis of a proposed project for the development of an industry at Green River for the manufacture of complete concentrated fertilizer mixtures, for shipment into what have been termed the "four tributary regions," the inference being that the proposed mixtures could be made at Green River and profitably marketed throughout the four regions. These regions comprise the following States:

Western:
- Washington
- Oregon
- California
- Nevada
- Arizona
- Utah
- Idaho
- Montana
- Wyoming
- Colorado
- New Mexico

West North Central:
- North Dakota
- South Dakota
- Nebraska
- Kansas
- Missouri
- Iowa
- Minnesota

East North Central:
- Wisconsin
- Illinois
- Indiana
- Michigan
- Ohio

South Central:
- Texas
- Oklahoma
- Arkansas
- Louisiana
- Mississippi

The location of the four tributary regions and the States included in them, is shown in the accompanying map.

Of these, the East North Central Region is the most distant from Green River, but it is a large consumer of mixed fertilizers, as will be noted from the following table 1. This emphasizes the desirability of producing mixtures of high concentration.

TABLE 1.—*Consumption of commercial fertilizer mixtures in the 4 regions tributary to Westvaco*

Region	Year ended June 30, 1947	Percent of total commercial mixtures	Year ended June 30, 1950	percent of total commercial mixtures
East North Central	2,197,698	43.4	2,612,740	44.4
West North Central	489,585	9.7	666,224	11.4
South Central	1,973,288	39.4	2,339,374	39.7
Western	378,147	7.5	266,011	4.5
Total	5,038,718	100.0	5,884,349	100.0

In table 2 are shown the weighted average nutrient contents for the four regions of table 1. These represent a close approximation of the fertilizer mixtures in actual present day use. Table 2 shows an average percent of concentration of the plant foods, nitrogen, N_2, phosphoric acid, P_2O_5, potash, K_2O, in the mixed fertilizers as marketed in the four regions during 1950, of 24.84 percent.

TABLE 2.—*Weighted average plant nutrient content expressed as percent of total fertilizer mixture in the 4 regions of the United States, more nearly tributary to Green River*

Region	N		P_2O_5		K_2O		Total	
	1947	1950	1947	1950	1947	1950	1947	1950
East North Central	2.28	2.73	12.58	13.02	8.50	10.93	23.36	26.68
West North Central	2.83	3.82	13.42	15.73	7.19	8.63	23.44	28.18
South Central	4.30	4.36	10.10	10.28	5.83	6.93	20.23	21.57
Western	8.81	9.39	10.60	11.77	4.55	5.77	23.96	26.93
Weighted average total concentration in fertilizer mixtures, produced in the 4 tributary regions in 1947 and 1950							22.19	24.84

For the purpose of this analysis, it will be assumed that the concentrated fertilizer mixture which would be produced at Green River would have an average concentration of the three principal plant foods of 49 percent, made up as follows: N_2, 8.2; P_2O_5, 23.3; K_2O, 17.5. This mixture has about twice the concentration of the mixtures produced in the year 1950, given in table 2, which may be assumed to be a close approximation of present-day fertilizer mixtures. Although having twice the concentration, the proposed complete concentrated mixtures at Green River will retain the same relative proportions of the plant food ingredients, and these can be varied over a considerable range to meet the local requirements of any particular region.

A typical concentrated mixture of 49 percent total plant food content, which can be used for the purpose of this analysis, as being proposed for production at Green River for marketing throughout the four tributary regions, is given in table 3, and is referred to as mix Ee.

TABLE 3.—*Mix Ee*

	Net tons annually
Total nitrogen, N_2	33,400
Nitrogen, N_2, as nitrate	20,000
Nitrogen, N_2, as NH_3, ammonia	13,400
Total available phosphoric acid, P_2O_5	95,200
Total potash, K_2O	71,300
Total potash, K_2O, as crude potassium nitrate, 14.36–0–37.3	35,650
Potash, K_2O, as muriate	35,650
Total plant foods	199,000
Total annual complete concentrated fertilizer mixture	407,500

It is assumed that the crude potassium nitrate would be produced by an improved base exchange process at Green River, utilizing the natural gas of the region to make nitric acid, which in turn would be used to make sodium nitrate from the trona, and this would then be used as the base exchange liquid to produce crude potassium nitrate by reaction with the wyomingite. The balance of the potash, which is used as muriate (KCl), would be purchased in the open market.

In round numbers, the total annual present-day consumption of ordinary complete mixed fertilizers in the four tributary regions is 6,000,000 net tons, which corresponds to 3,000,000 net tons of the proposed complete concentrated fertilizer mixture of table 3. Thus, in supplying the entire requirements for mixed fertilizer of the four tributary regions, this proposal would save freight on 3,000,000 tons. A careful analysis shows that the weighted average freight rate from Green River to points of destination in the four regions, is $12.70 per ton (as of December 1951), giving a total saving in freight of about $38,000,000 annually, which comes close to $50,000,000 when the saving on the bags is included.

MARKETS EXPANDING

Plant estimated in table 3, producing as it would 407,500 tons annually, would only provide about 13.6 percent of the total present market for contained plant foods in the four tributary regions. These markets are constantly growing, and in addition, the advantage of high concentration for shipment over the long distances involved, is so real and apparent that a much larger proportion than 13.6 percent of the total would be expected to be provided a few years after the establishment of the first unit.

The capital investment required in the first unit for producing 407,500 tons annually of the 49 percent concentrated complete fertilizer mixture, is estimated at $30,000,000. The mill net price for the proposed mix Ee of table 3, which is after deducting the weighted average freight of $12.70 per net ton, is $65.90, giving a total annual mill net sales of $26,850,000. This gives a dollar investment per dollar of annual sales of $1.12, which is a very satisfactory figure. The freight, expressed as percent of the mill net sales value, is 19.4 percent, which is also not excessive.

A variation in this proposal which could be carried out in whole or in part would be to manufacture all of the potash by base exchange, but it does seem that there may well be an advantage in mixing the two types of potash. This is one of the variations which may be employed to control the type of mixture produced.

PROCESSES SIMPLE

The proposed process is subject to the possibility of considerable variation in the relative amounts of nitrogen, phosphoric acid, and potash which the mixtures contain. This is an important property because there is a variation in the analyses from region to region. Furthermore, the process is characterized by simplicity, the final concentrated mixed fertilizer being made by combination of the several ingredients, which mixture is first produced wet and is then dried and granulated in a rotary drier.

The mixtures which have thus far been produced under this proposal have been on a laboratory scale but the procedure is so simple that no particular difficulties are expected in going to a larger scale of operation. However, the next steps must be to erect and operate a pilot plant on a fair scale of operation, testing the products by application to the soil.

In conclusion, it will be of interest to note the consumption of the three principal plant foods as complete fertilizer mixtures in the four

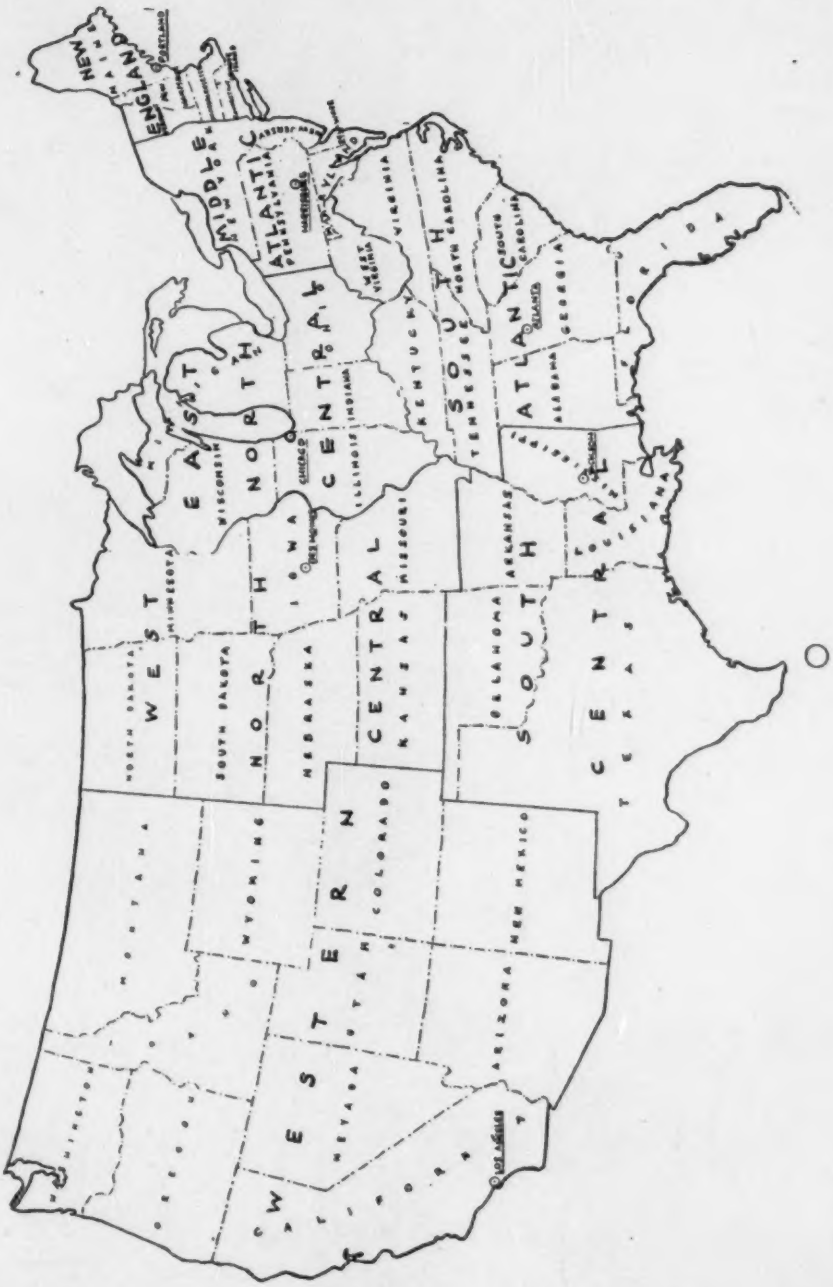
tributary regions, and to compare these totals with the total consumption in the United States in 1950 of nitrogen, N_2, phosphoric acid, P_2O_5, and potash, K_2O, based upon data of the United States Department of Agriculture. These figures are presented in table 4.

TABLE 4.—*Total consumption of the principal plant foods in the 4 tributary regions, as complete fertilizer mixtures, as compared with the consumption in the entire United States*

Region	Net tons annually		
	Nitrogen N_2	Phosphoric acid, P_2O_5	Potash K_2O
East North Central	71,400	341,000	286,000
West North Central	25,500	105,000	57,600
South Central	102,000	241,000	162,000
Western	25,000	31,300	15,370
Total in the 4 tributary regions as complete mixtures	223,960	718,300	520,970
Total in the entire United States	1,026,004	2,088,391	1,081,876
Percent of total in the United States as mixtures in the 4 tributary regions	21.7	34.5	48.1

Table 4 brings out the interesting fact that while the consumption of potash in the western region is relatively insignificant, its consumption in the selected four tributary regions is relatively very high, amounting to about 48 percent of the total consumption in the United States. It is evident that because the present total consumption of fertilizer is great and is known to be rapidly growing, that insofar as distribution of a large quantity of fertilizer is concerned, Green River is well situated.

ROBERT D. PIKE.


NEW ENGLAND
MAINE
PORTLAND
MIDDLE ATLANTIC
PENNSYLVANIA
HARRISBURG
EAST NORTH CENTRAL
WISCONSIN
ILLINOIS
CHICAGO
INDIANA
WEST NORTH CENTRAL
MINNESOTA
IOWA
OKLAHOMA
MISSOURI
SOUTH ATLANTIC
VIRGINIA
RICHMOND
KENTUCKY
TENNESSEE
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SOUTH CAROLINA
GEORGIA
ATLANTA
ALABAMA
MISSISSIPPI
EAST SOUTH CENTRAL
ARKANSAS
LOUISIANA
WEST SOUTH CENTRAL
TEXAS
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
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